Consistent Euler-Lagrange approach for particulate flow modelling with arbitrary particle size/mesh resolution ratio

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Euler-Lagrange approaches are widely used for the numerical modelling of complex particulate flows owing to their relatively low computational cost and the straightforward modelling of particle-particle interactions. Since relying on an assumption of separation of scales between the general features of the flow, which are resolved on the Eulerian fluid mesh, and those at the scale of the Lagrangian particles, which are modelled based on simplified theoretical/empirical models, Euler-Lagrange methods typically require the tracked particles to be much smaller than the cells forming the mesh on which the flow equations are solved. For cases that present high refinement requirements, for instance due to the presence of boundary layers or complex geometry features, this can drastically limit the size of the particles that can be accurately tracked within the flow.

In this contribution, we propose an Euler-Lagrange approach that is free of such restrictions. It relies upon the filtering of the instantaneous flow equations with a particle marker function; a process in which a length-scale is chosen. This decouples the size of the particle with the specific length of the discretised mesh cell in calculating the volume fraction. This filtering is also applied to the fluid-particle momentum coupling terms, which provides a solid framework for spreading these source terms. Throughout the application of the proposed method to a number of test-cases, we show that the filtering strategy allows for the consistent tracking of Lagrangian particles regardless of their size relative to the Eulerian mesh, as shown in Figure 1. The method is then applied to large-scale particulate flows, namely: a turbulent channel flow and a fluidised bed, and the impact of the proposed filtering on the statistics of the flow is investigated.

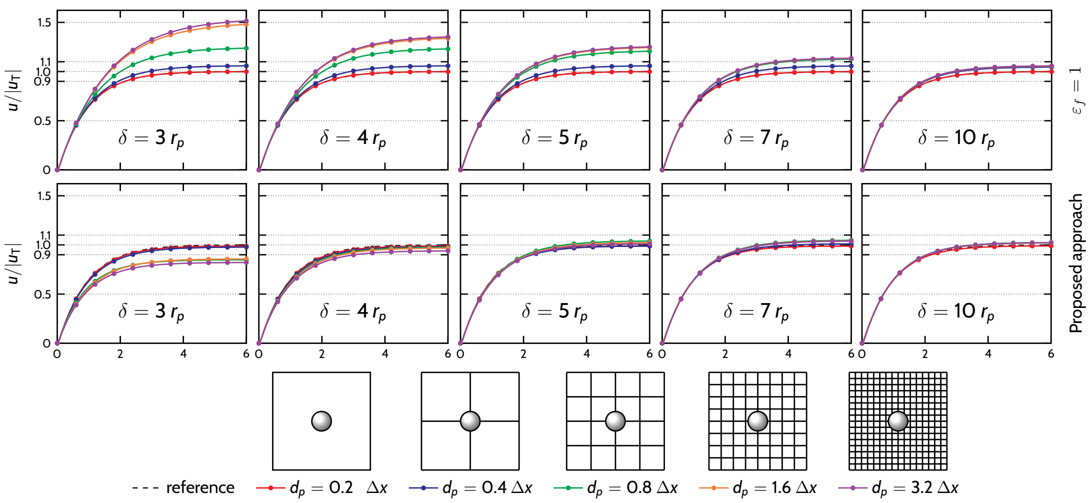

Figure 1: Time-evolution of u, the velocity of a single Lagrangian particle settling under the influence of gravity in quiescent fluid, normalised with respect to its terminal velocity u_{T}. Resolutions ranging from $r_p = 0.2\ \Delta x$ to $r_p = 3.2\ \Delta x$ are considered (where r_p is the radius of the Lagrangian particle, and Δx the Eulerian mesh spacing). The radius of the filter support, δ is varied from $\delta = 3\ r_p$ to $\delta = 10\ r_p$. The proposed approach yields consistent results with varying mesh resolution for δ/r_p as little as 4.